Free-carrier Densities in *n*-doped Si

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For Si device structures to continue shrinking, free-carrier densities must continue to increase. Realizing the fundamental and practical limits for achieving the highest free-carrier densities in *n*-doped Si forms the basis of this work. It had been shown that doping Si with high concentrations of Sb at low MBE growth temperatures (to avoid forming Sb precipitates and to minimize Sb diffusion) yielded carrier densities that depend strongly on whether the Sb atoms are distributed in 3D (bulk-doped) or 2D(δ-layer-doped). A model to explain this had been proposed, which involves electrically deactivating donor-pair (*DP*) defects. Such defects are inhibited (frustrated) from forming in 2D, resulting in higher concentrations of electrically active dopants.

This year, three courses of action have been pursued. First, new 2D-doped samples were grown and characterized by x-ray absorption, scanning transmission electron microscopy (STEM), and Hall measurements. The results demonstrated that with low-temperature MBE, the maximum effective dopant concentration of Sb is ~10% and the maximum electrical activity is ~65%. The new data also further supported the 2D-geometric-frustration model. Second, positron annihilation measurements were performed on 3D Sb-doped samples in search of additional evidence for *DP* defects. The results were inconclusive, and showed the need for STEM measurements, which are planned. Third, the highest 2D-doped samples were subjected to the highest annealing temperatures used in early processing of conventionally (3D-) doped Si. The motivation for this was to explore the feasibility limits of manufacturing δ-layer-doped Si devices. Analysis with STEM showed that the Sb dopant atoms had formed precipitates. Since these temperatures exceed limits for processing other components in newer Si device structures, lower temperatures are planned for further testing and characterization.